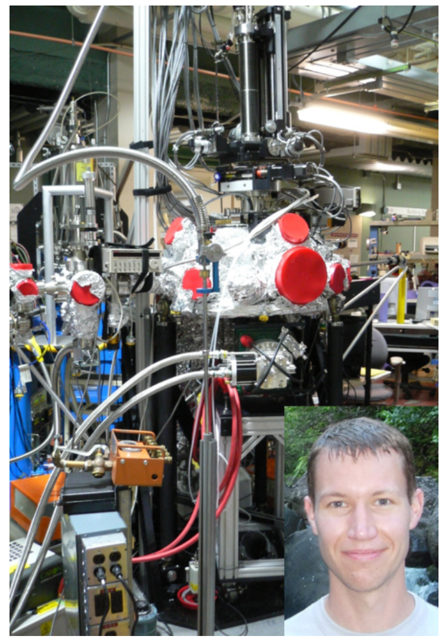
Postdoctoral Fellowship Highlight

Padraic C. Shafer, Ph.D., Physics

Years of Fellowship: 2010-2012
Collaborating Institutions: University of California, Berkeley
Currently: ALS Beamline Scientist

Project: **A new experimental setup that allows resonant soft x-ray scattering experiments in high magnetic fields for the study of correlated electron systems.**

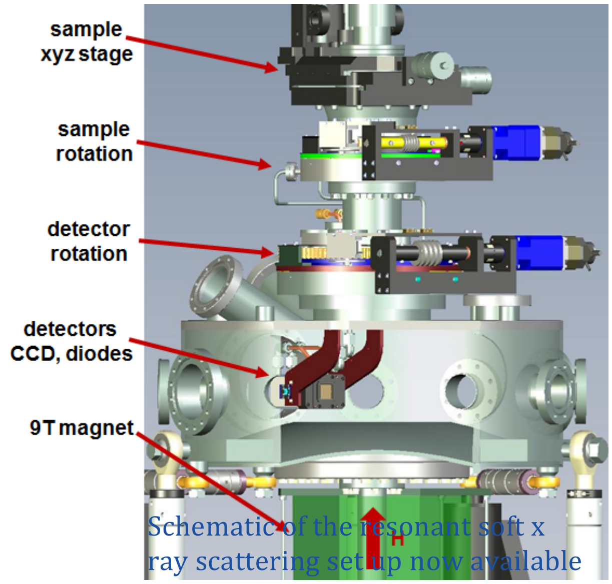


Resonant soft x ray scattering set up developed by Padraic Shafer as ALS postdoctoral fellow.

Correlations are the essence of nature and also occur in everyday life. For example, people in a car are strongly correlated in both space and time. To adequately predict the behavior of a system (e.g. trajectory of the car), a detailed understanding of the interactions is essential. In strongly correlated electron systems such as transition metal oxides, the Coulomb interaction between electrons occupying the same narrow 3*d* band is enhanced by the spatial confinement of the electrons and leads to intriguing phenomena such as high temperature superconductivity, giant magnetoresistance, multiferroics as well as electronic superstructures on the nanoscale. To better understand these novel phases is not only interesting for fundamental research but also relevant for future technological applications, e.g. sensors and switches and electronic devices with novel functionalities.

As an ALS Posdoctoral Fellow, Padraic Shafer developed and commissioned a new experimental setup that for the first time allows resonant soft x-ray scattering (RSXS) experiments in high magnetic fields for the study of correlated electron systems. By cooling a 1 inch disc of the high temperature superconductor YBaCuO in a high magnetic field and then reducing the external field to zero, Padraic was able to induce very large current densities (>2000A/mm^2) in the YBaCuO disc which in turn create magnetic fields of up to 5T at the disc surface. By placing a sample of interest on the YBaCuO surface, Padraic is now able to perform RSXS experiments in high magnetic fields with full access to the sample surface. During the design and commissioning of the instrument, Padraic collaborated with ALS scientist as well as LBNL engineering and technical experts. Through one of these collaborations, Padraic developed a theoretical model to predict the current distribution in the YBaCuO disc and with that, the magnitude and spatial variation as function of the cooling field. This allows him to precisely tune the magnetic field for his studies of correlated electron systems.

In RSXS experiments that Padraic performs at BL4.0.2, the photon energy is tuned through the transition metal $L_{3,2}$ and edges and electrons are excited into unoccupied intermediate states. RSXS is therefore element-, valence- and site-specific as well as sensitive to the spin and orbital state of the absorber. In fact, resonant scattering represents a combination of structure determination and spectroscopy since constructive interference of x-rays occurs only in geometries determined by the periodicity of the superstructures and is resonantly enhanced only at photon energies characteristic for a particular electronic (charge, spin or orbital) state. Since the x-ray wavelength near the transition metal $L_{3,2}$ edges matches in many complex oxides the period of the charge, spin and orbital order, this technique is uniquely suited to elucidate the origin of electronic superstructures induced by electron correlations in transition metal oxides.



Schematic of the resonant soft x ray scattering set up now available at ALS BL4.0.2.

Padraic used the setup to characterize the impact of magnetic fields on the electronic and spin order of manganites exhibiting giant magnetoresistance, i.e. a dramatic transition between insulating and conducting behavior upon application of a sufficiently strong, i.e. several T, magnetic field. Moreover, he gained new insights in the magnetic structure of domain walls in the multiferroic $BiFeO_3$. Padraic complemented the scattering experiments with soft x-ray magnetic dichroism measurements using unique instrumentation only available at BL4.0.2. He became an expert in optimizing the beamline for the measurement of very small dichroism effects, which was critical for his experiments.

The RSXS endstation Padraic developed is now available for the ALS user community at BL4.0.2 and Padraic became an ALS beamline scientist in October 2012. He collaborates with ALS users on resonant soft x-ray scattering and dichroism experiments elucidating the origin and impact of electron correlations.